knowledge of the asteroids, etc., will be gained by this decision. But would it not be possible to take up this constantly required work in other quarters according to the principle of a division of labor?

In the old world it is more than likely that all larger astronomical institutes have their set plan of work for years and decades to come, to which such a considerable amount of extra and continuous labor could not well be added. Involuntarily we turn our face to North America, where new and extensive astronomical institutions, generously endowed with instruments, money and assistants, are constantly created. *Could not one of these make it a special object to furnish regular computations, accurate enough for all purposes of the discoverer at least, of those planetoids that are now left unconsidered in Berlin, and to publish them in almanacs, etc., for coming years?* It would seem as though this were a good work of considerable importance — a work which would meet with greater approval by many than, for instance, the effort to eclipse the gigantic telescopes of the day by the creation of a still larger one. At all events, the idea may deserve the attention of those interested on "the other side."

ON THE PHOTOGRAPHS OF THE MILKY WAY MADE AT THE LICK OBSERVATORY IN 1889.

By E. E. Barnard.

It seems desirable to give a brief description of the photographs of the Milky Way made by me at the Lick Observatory in 1889, and to call attention to their special and important points which might otherwise be overlooked by those not familiar with celestial photography, and thus their value be under-estimated for the purpose for which they were made. It was intended to show, as far as possible by photography, the wonderful and complex structure of the Milky Way.

One very important feature, and one which must not be overlooked, is that these are the only photographs ever made, here or elsewhere, which show at all the true Milky Way.

The structure of the Milky Way is invisible in the telescope because of the limited field of view; for we see, comparatively, only a few of the individual stars whose combined light illuminates the sky and aids in giving the clouded appearance which is so conspicuous

to the naked eye. And here it may not be unimportant to remark that the vast majority of the stars whose light goes to make up the true Milky Way cannot be seen in any telescope ever constructed—they are individually so small and faint. It is therefore impossible to obtain any idea of the structure of the Milky Way from telescopic observations alone, because of the limited field and the faintness of the smaller stars.

In a photographic experience of twenty-five years, I have never seen anything more deceptive to photograph than the Milky Way. From some of the first experiments, made with a small camera, it seemed impossible to photograph it, the sensitive plate apparently picking out only the individual points of light. To the eye, the Milky Way is a bright and conspicuous object, and at first it would seem as if an impression of it would be made with a comparatively short exposure. A few experiments, however, showed the hopelessness of this. If we consider that this nebulous appearance of the sky is due to an infinite number of invisible points of light, and not to an illuminated background such as nebular light, it would seem that a photograph of the true Milky Way would be impossible. It is, in fact, by no means easy—for the exposure must be very long, and the instrument must be watched and kept constantly fixed on some one star of the proposed picture every moment for several hours; and when all this is properly done, the plate requires the utmost delicacy of treatment in developing.

The possibility of photographing the true Milky Way at all is explained by the following theory:

If we look at a dense cluster of stars, too closely packed for the instrument to distinguish the stellar points, it appears as a nebula, or is continuous in its light. Increase, now, the dimensions of the telescope, and the nebulosity disappears and we see each individual point of light. In the Milky Way the stars are crowded together by distance. If we could approach it, which we can do, in a sense, by the telescope, we should separate the stars in proportion to the lessening of our distance, or the size of our telescope. The eye is too feeble to pick out the individual stars of the Milky Way, or to separate them; it therefore perceives only a nebulous or clouded appearance, and is really impressed by a *quantity* of light which is made up altogether of individually invisible sources. The sensitive plate is not thus deceived, for its action depends upon the *intensity* of the light, and it therefore picks out each individual point, if the lens is good.

Applying these remarks now strictly to the Milky Way, we should

find that by continuing the exposure long enough, the multitudes of stellar points which form the cloud masses would come into view so thickly on the plate as to blend together and form a more or less continuous surface, thus giving the exact cloud structures as they exist in the heavens. Now, a lens of the same light-ratio, but giving a larger scale, with the same exposure as the foregoing, would show only a great number of separate stars, without indicating anything of the cloud structure proper. A much longer exposure would, therefore, be required to bring other stars into view sufficiently numerous to fill the spaces before the true structure would again appear. We should, therefore, finally come to a point, by increasing our scale, at which no exposure possible would be sufficiently long to reproduce the true Milky Way. By increasing the scale beyond a certain limit, the characteristic structure is lost.

But there is also a certain point where the lens cannot show the true structure, because of the smallness of scale and the deficiency of penetrating power; that is to say, a very small lens would not show the structure with sufficient distinctness to be of any special value. The photography, therefore, of the true Milky Way must be confined to instruments of medium dimensions—with large apertures and small focal lengths—until our plates can be made much more sensitive, or the exposures extended through several nights.

The splendid pictures made by the HENRY brothers at Paris, considered as photographs of the stars, have never been equaled by any other astronomers with any telescope. The stars are wonderfully sharp and round, and a print from one of their negatives is almost as perfect as if made from a steel plate. I have before me now one of their photographs of a portion of the Milky Way in *Cygnus*. It is a perfect specimen of the photographic art, and shows a vast number of stars on a black sky; but there is no trace, or even a suggestion of the Milky Way proper, and it might fairly refer to any other portion of the heavens than the Milky Way save for the number of stars depicted. This picture represents the finest work yet done in stellar photography.

In the photographs made with the six-inch portrait lens, besides myriads of stars, there are shown, for the first time, the vast and wonderful cloud forms, with all their remarkable structure of lanes, holes and black gaps and sprays of stars. They present to us these forms in all their delicacy and beauty, as no eye or telescope can ever hope to see them; while the individual stars, near the middle of the plates, are as round and perfect as are those made at Paris.

The lens used in this work was of the ordinary portrait combination, having an aperture of six inches and a focal length of thirty-one inches. This lens, attached to a box of the proper size, was firmly strapped to the tube of the six-and-a-half-inch equatorial. As no driving clock is so perfect as to keep a telescope moving with the apparent motion of a star for any considerable length of time, it was necessary to keep the eye fixed upon a star bisected by cross wires in the eye-piece, and to correct the motion of the telescope by hand with the slow-motion rods throughout the long exposures. One of these exposures thus made,—the longest,—was five hours and ten minutes.

I have been able, so far, to make negatives of only three portions of the Milky Way with this lens, as it has not been available since last summer.*

The most wonderful of these Milky Way pictures is the one in the constellation of *Sagittarius* (R. A. $17^h\ 56^m$, Dec. South 28°), a region which I specially selected as possessing the most intricate and complex structure of any portion of the Milky Way above our horizon. This was given an exposure of $3^h\ 7^m$.

The only other celestial photographs that I have made were also taken with the portrait lens. They are the Great Nebula of *Andromeda*, exposure $4^h\ 18^m$; the *Pleiades* and the *Merope* Nebula, $1^h\ 15^m$; the Trifid Nebula, $4^h\ 5^m$; Davidson's Comet, $1^h\ 30^m$. From the short focus of this lens, these nebula pictures are necessarily on a small scale (1 in. = 1°.8.)

Although these pictures of the nebula are very perfect, yet they must not be compared with the photographs of the nebulæ taken by Mr. ROBERTS and Mr. COMMON without proper consideration of the instruments that made them. Mr. ROBERTS works with a reflector of twenty inches diameter and one hundred inches focus; while Mr. COMMON has used a thirty-six-inch reflector, and now is using a telescope five feet in diameter. The HENRY brothers employ a photographic telescope with a lens thirteen inches in diameter. Allowing for the difference in the size of the instruments, my photographs of the *Andromeda* Nebula, etc., compare most favorably with anything made by these astronomers. The picture of the *Andromeda* Nebula, made with the portrait lens, though on so small a scale, shows nearly every detail that is on Mr. ROBERTS' photograph, acknowledged to be the best photograph ever taken of a nebula; and, while it is

* This lens is now having a mounting made for it, which Hon. C. F. CROCKER has presented to the Observatory.

necessarily lacking in what is due to scale, it shows the wonderful structure of the region in which the Great Nebula is situated as nothing else has ever shown it.

Some of the above pictures made with the portrait lens have been beautifully reproduced in *Knowledge* of July and August (A. C. RANYARD, ed., 67 Chancery lane, London, W. C.). The July (1890) number of that journal has a full-page reproduction of the Milky Way picture in R. A. $17^h\,56^m$, Dec. — 28°, done in an admirable manner by the Direct Photo-Engraving Company, of London, and is accompanied by an article by the editor on the singular features shown on the photograph.

MT. HAMILTON, August, 1890.

BLACK TRANSIT OF *JUPITER'S* SATELLITE IV.

BY C. B. HILL.

While entertaining a party of visitors at the Chabot Observatory on August 13, I turned the 8.5-inch equatorial on *Jupiter*, and noticed that the fourth satellite, then in transit, was outlined against the apparent lower limit of the N. belt as a perfectly black spot, even more pronounced in its blackness than is the usual shadow.

This was at 9:10 P. M. Pacific standard time; and as soon as the visiting party had left the observatory, I went to the telephone office, and notified Professor BARNARD at the Lick Observatory, knowing him to be especially interested in this class of phenomena, only to find (as might have been expected) that this event had not escaped the astronomer in his nightly comprehensive sweep of the heavens.

Resumed observations 10:10 P. M. Satellite IV, equally black; seemingly internally tangent to N. line of belt, and followed by two little dark spots. Under highest powers (400, 500), satellite still remained strikingly black, and to my eye *perfectly circular*, while the details of the belts, and all trace of the other dark spots were lost in the indistinct vision.

Made sketch of the planet 10:30–10:45. First dark spot closing up on satellite, on account of the rapid rotation of planet. Image of IV now seemed to me rather grayer. Consulted ephemeris, and found that the entry of shadow and the leaving of the last train for the city